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THE ROLE OF THE HIMALAYAS AND THE TIBETAN PLATEAU WITHIN THE ASIAN MONSOON SYSTEM

BY MASSIMO BOLLASINA AND SAM BENEDICT

Research priorities for modeling and observations were established as part of the planning for the Coordinated Enhanced Observing Period of the Global Water and Energy Cycle Experiment.

The key mission of the Coordinated Enhanced Observing Period (CEOP) is to understand water and energy cycles, document their physical processes, and simulate and predict water and energy fluxes. This involves a synergetic strategy integrating satellite data, in situ observations, assimilated data, and modeling simulations. A CEOP Monsoon Systems Working Group has been organized to address some of the main CEOP aims: documenting the seasonal march of the monsoon systems, assessing their driving mechanisms, and investigating the possible physical connections between such systems. In this context, the CEOP Inter-Monsoons Model Study (CIMS) was defined to validate and assess the capabilities of models in simulating monsoon processes. The objectives of this international project are to improve understanding of the fundamental physical processes underpinning the diurnal to annual cycles in the monsoons of Asia, Australia, North America, South America, and Africa, and to demonstrate the synergy and utility of the CEOP data integration strategy.

Within the Asian monsoon system, it is well known that the Himalayas and the Tibetan Plateau exert profound thermal and dynamical influences on atmospheric circulation. Thus, at the Global Energy and Water Cycle Experiment (GEWEX) CEOP workshop on the role of the Himalayas and the Tibetan Plateau within the Asian Monsoon System, held on 7–8 April 2003 in Milan, Italy, it was important to briefly review the current understanding of physical processes occurring in these high-altitude and extended regions, and to examine their relations with and the influence of the global monsoon circulation at different spatial and temporal scales. Within the

AFFILIATIONS: BOLLASINA—Epson Meteo Centre, Milan, Italy; BENEDICT—CEOP International Coordinator, Coronado, California
CORRESPONDING AUTHOR: Massimo Bollasina, Research and Development Division, Epson Meteo Centre, via M. Viganó de Vizzi, 93/95, 20092 Cinisello Balsamo, Milan, Italy
E-mail: massimo.bollasina@epson-meteo.org
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framework of CIMS, the workshop focused on model physics improvement (via simulations) and the cross validation of model outputs with detailed observations. A critical part of this work is the synergistic use of global data, in conjunction with high-resolution observations from field sites, including the Himalayas and Tibetan Plateau. Some of the main tasks were to identify the key processes, the parameters to be validated, and the specific requirements from the validation sites. (Information on the agenda, participants, and presentations may be found online at http://news.epson-meteo.org. Updated information on CEOP implementation status is available at www.ceop.net.)

The workshop permitted the fruitful examination of different aspects of Himalayan and Tibetan regions in connection with the Asian monsoon system. A summary of the state-of-the-art physical process studies and connections with large-scale monsoon circulation and the global monsoon system highlighted reciprocal influences at different space and time scales. The workshop also outlined common aspects and results of the studies to highlight key parameters and model deficiencies to be further investigated for a better understanding of circulation, to emphasize the fundamental physical processes modulating monsoon circulation, and to demonstrate the synergy and utility of CEOP strategy of integration among different sources of data in such regions.

The workshop resulted in a set of issues/recommendations for CIMS work.

REFERENCE SITES COOPERATION. High-altitude observations and processes are important in the integration of data and observations for model physics evaluation and improvement. Enhanced observations made at the Tibetan Plateau/Himalayas reference sites through the GEWEX Continental-Scale Experiments, together with the observations from other sites, will provide CEOP with the basic resources necessary to achieve one of its main scientific objectives. In this regard, coordination between the Himalayas reference site and Marsyandi River basin (central Nepal) during the second CEOP annual cycle period (EOP-4) was strongly encouraged. High-altitude climate over the Himalayas and the Tibetan Plateau has to be further investigated, with particular attention to land–atmosphere interactions and their effect on the Asian monsoon circulation in terms of driving forces (heat and moisture sources and sinks) and feedback mechanisms (in the energy and hydrologic cycles). Similarity, connectivity, and differences among western and eastern Himalayas and the Tibetan Plateau, and between low- and high-altitude climate, have to be highlighted, especially in terms of stratiform and convective precipitation, wind circulation and moisture transport, and orographic forcing.

MODEL VALIDATION AND IMPROVING MONSOON PREDICTABILITY. It was recommended that monsoon analysis, understanding, and predictability be improved by merging different points of view and approaches and by following the CEOP downscaling strategy. This will involve integration of remote sensing observations by satellites, surface/upper-air observations at reference sites, and numerical model analysis and simulations (from global to regional circulation models). Monsoons involve the interactions among many components of the climate system and, therefore, fundamental physical processes in the models have to be well parameterized. Many of the discussions highlighted different key physical processes and parameters to be further analyzed/investigated, including land surface processes, atmospheric boundary layer processes, atmospheric heating, precipitation, and ocean data.

Land surface processes. Land surface conditions (e.g., surface roughness, snow cover, and soil moisture) modify the thermal contrast between land and ocean. Land–atmosphere physical processes are linked by means of complex feedback mechanisms involving heat fluxes, precipitation, and convection. Numerical model sensitivity experiments with different parameterizations will help us understand these interactions. Attention has also to be paid to how well vegetation and soil are described in models (heterogeneity), in terms, for example, of vegetation cover (and its monthly variation) and soil characterization. Regarding the Himalayas/Tibetan Plateau region, land surface models are to be particularly tested against observations, in order to check the ability to reproduce characteristic features (e.g., permafrost) affecting ground heat flux and soil moisture.

Atmospheric boundary layer. High-altitude climate is strongly characterized by the diurnal cycle of many parameters. Among the issues of the greatest interest are the measurement and simulation of fluxes within the ABL; their monthly variation in relation to the onset, maintenance, and withdrawal of the monsoon; and their characteristics within the diurnal cycle (e.g., time of maximum). Moreover, the importance of mountain–valley circulation over these regions and how the monsoon circulation at a large scale interacts with this kind of circulation regime was demonstrated.

Atmospheric heating. In the monsoons, the land–sea thermal contrast modifies circulation of the overlying atmosphere and precipitation develops. It is, therefore, important to evaluate how large-scale atmospheric heat and moisture budgets, as given by the well-known residuals Q_1, the apparent heat source, and Q_2 the apparent moisture sink, vary over space and time. This is especially useful in the study of the onset phase of the monsoon and its intraseasonal variability, and in the analysis of the relative importance of sensible and condensation heating.

Precipitation. The analysis of temporal and spatial scales of precipitation and their characteristics is crucial for the determination of the water cycle and the evaluation of water reservoirs and the regional hydrologic cycle. Specific issues to be addressed are the documentation and simulation of the diurnal cycle of precipitation, and its characteristics (stratiform/convective) in relation to the variation of air stability and wind flow; the understanding of orographic effects on precipitation pattern; the analysis of synoptic–mesoscale interaction through, for example, large-scale moisture transport and convergence, and intraseasonal oscillations of the Asian monsoon system; the analysis of the structure of convection; and the study of the seasonal march and shift of precipitating areas (east–west, south–north, bottom–top).

Ocean areas. In view of the importance of the land–sea thermal contrast in driving the monsoon, there is a need for an improvement of ocean data. These will include surface data (e.g., sea surface temperature, sensible and latent heat, water vapor and momentum fluxes, and net radiation), as well as upper-ocean (mixing layer) data (e.g., vertical thermal structure and heat flux).

MONSOON ISSUES. In relation to general discussions of the monsoon, some recommendations were made concerning both large-scale analyses and local-scale process studies. Within the annual cycle of the monsoon, it was suggested to focus especially on the onset phase (role of surface processes and of sea surface temperature anomalies) and on active/break cycles (and their relation, e.g., to land surface heat and moisture processes, to their intraseasonal oscillations, and, in general, to the interactions among land, atmosphere, and ocean processes).

Winter plays a very important role in the development of the Asian monsoon system through the effect of anomalous snow cover and/or soil moisture. As a result, there was agreement to also study the relations between winter and summer monsoon circulation.

On the interannual scale, it is important to document how the variations in monsoon circulation are directly related to the local hydroclimate (including glacier lake outburst floods) and to the availability of water reservoirs. The main questions in these cases are as follows: What are the controlling large-scale and long-term factors, and to what degree can the related water fluxes be simulated and predicted?

Moreover, monsoon systems have to be compared in view of global monsoon climate system, in search for not only differences and similarities, but also interconnections. This will be directly translated into the CIMS "telescoping" approach, which coordinates model integrations from general circulation models of the atmosphere, through regional climate models, to cloud resolving models.

COOPERATION WITH OTHER PROGRAMS. It will be necessary to coordinate CIMS activities, which originally evolved in the Monsoon Systems Working Group, directly with the work planned under the CEOP Water and Energy Simulation and Prediction (WESP) Working Group. This is necessary because WESP addresses the CEOP aim to enhance observations to better document and simulate water and energy fluxes and reservoirs over land on diurnal to annual temporal scales, and to better predict these up to seasonal scales. WESP will result in a better understanding of model physical processes, in particular, in a better understanding of the difficulties in depicting diurnal and seasonal cycles and in requirements for their improvements. In this context, joint work of CIMS and WESP is strongly recommended.

CIMS should be considered a pilot research effort whose aims are addressed to the broader World Climate Research Program (WCRP) community. Therefore, the work should be carried out in connection with GEWEX and the Climate Variability and Predictability Programme (CLIVAR) and within the framework of existing monsoon panels, initiatives, and field programs.

One particular area of scientific and programatic synergy is the Asian brown cloud (ABC), which has been studied by scientists during the Indian Ocean Experiment (INDOEX; e.g., UNEP and Center for Clouds, Chemistry and Climate 2002). This brown haze occurs from January to March over the south Asian region and the tropical Indian Ocean, Arabian Sea, and Bay of Bengal, and has led to a considerable scientific interest, as well as concern. Of immediate importance is the relationship between the ABC and the Asian monsoon. For instance, how can the haze's radiative forcing influence regional and global monsoon climate, altering, for example, the hydrological cycle (with profound consequences on agriculture, water availability, etc.)? There is also the question of the impacts of the ABC on model simulations of the Asian monsoon (radiation parameterizations, etc.).

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